Synopsis of USGS studies on coastal processes and hazards along the Arctic coast of Alaska
Pacific Coastal and Marine Science Center (PCMSC), Santa Cruz, California

Project website: http://walrus.wr.usgs.gov/climate-change/hiLat.html
This site is in its infancy but will be populated within the coming months. It contains links to downloadable reports and oblique photography of the North Slope.

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- Arctic Landscape Conservation Cooperative (ALCC), http://arcticlcc.org/
- Alaska Science Center (ASC), USGS, http://alaska.usgs.gov/
- Alaska State Division of Geological and Geophysical Surveys (DGGS), http://dggs.alaska.gov/
- University of Alaska Anchorage (UAA), http://www.uaa.alaska.edu/collegeofengineering/research/arctic-coastal.cfm
- University of Alaska Fairbanks (UAF), http://ine.uaf.edu/

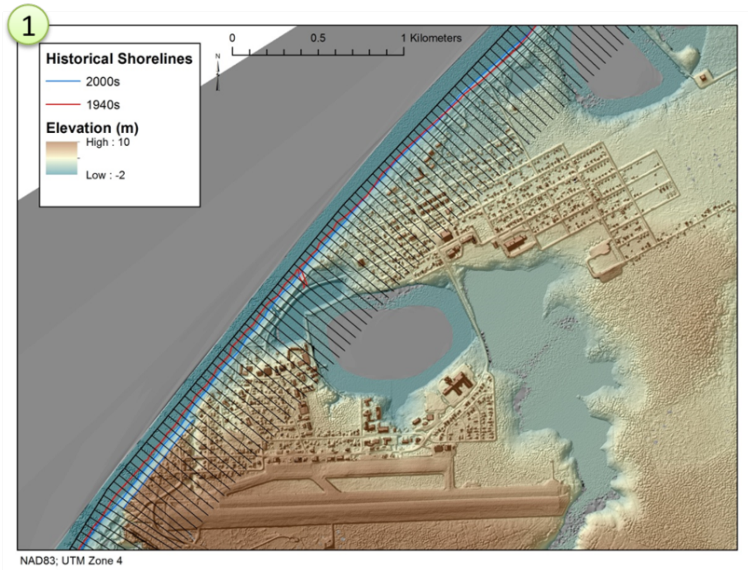
I. Overview

Researchers at the USGS Pacific Coastal and Marine Science Center have been actively investigating coastal change in Alaska for the last decade. Our work is primarily focused on evaluating flooding hazards, documenting shoreline change, and understanding the state and movement of subsurface water, both in the context of historical observations and projected conditions associated with climate change. Flooding hazard evaluations are based on numerical models that use atmospheric forcing for both the recent past (1980s to the present) and projected future climate (to the year 2100). The shoreline change work is part of the USGS National Assessment of Coastal Change Hazards project. The study quantifies shoreline change rates from historical data (1940s-2010s) and evaluates physical processes driving change. Nascent work on understanding subsurface hydrologic flow, carbon input to the ocean and atmosphere associated with coastal erosion and permafrost degradation, and subsurface geology will combine with model outputs to improve assessments of coastal hazards and future landscape change. Studies to date are primarily focused on the Arctic coastal region along Alaska's North Slope. We are planning for expansion of efforts to develop data and products to forecast and respond to climate-driven coastal change in Alaska and the Arctic. Engagement with state, local and tribal entities, and with DOI resource managers, would guide systematic development of products for this region where vulnerable landscapes, ecosystems, and communities face unique and consequential impacts of coastal change in response to sea-level rise, changing ice-cover and coastal processes, and increasing retreat associated with permafrost decline, inundation, and land subsidence. Substantial data gaps, including mapping of coastal landscapes and change, would be addressed to provide observational inputs to coastal vulnerability and change forecasts.

The following three pages provide brief overviews of the types of data and information we are generating.

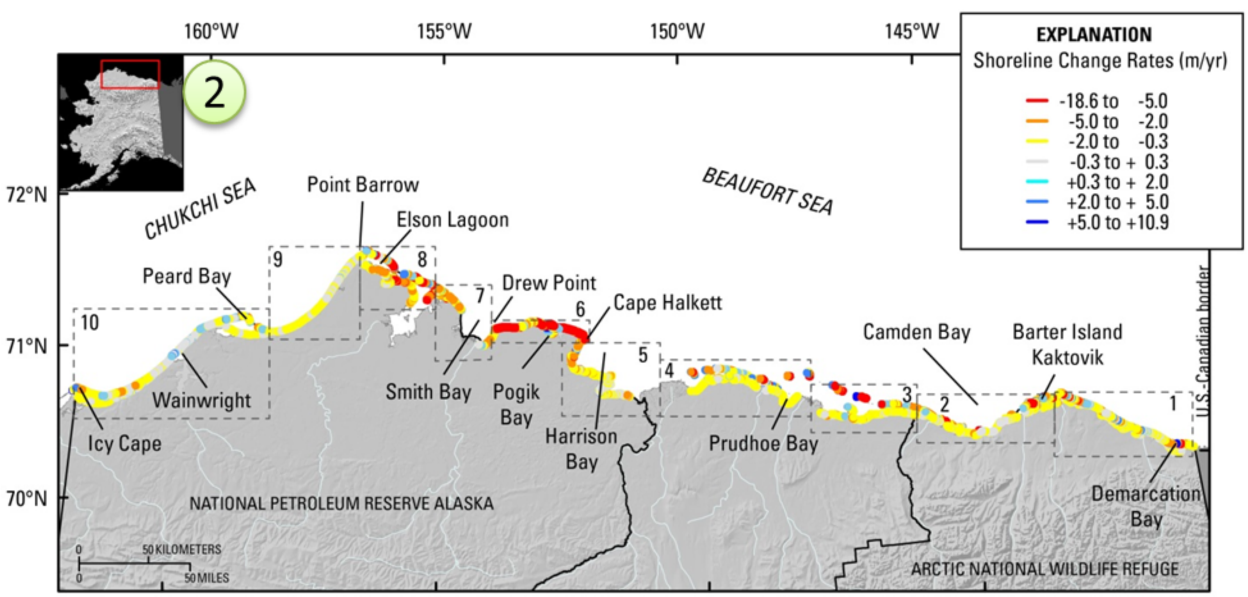
II. Shoreline Change

As part of a U.S. Geological Survey assessment of coastal change hazards, over 11,000 km^2 of airborne lidar elevation data were collected along the Arctic coast of Alaska between 2009 and 2012. Data coverage includes the barrier islands and mainland coast between Icy Cape and the U.S.–Canadian border, from the shoreline to ~1.5 km inland. This is one of the first comprehensive lidar datasets collected in a continuous permafrost environment. Many periglacial landscape features, such as patterned ground, ice-wedge polygons, and thermokarst lakes and former lake basins (recent and relict) are discernible in the dataset. Traditional coastal landscape features including shoreline position, beach width, slope, and bluff height and morphology are also distinct. An example is shown in Figure 1.



Example of airborne lidar overlain with historical shorelines and cross-shore transects where shoreline change was calculated. Image shows the City of Barrow, Alaska.

The lidar data complemented with older sources were used to calculate shoreline change rates for the entire North Slope. A variety of data sources were used to identify past shoreline positions so that the analyses can extend as far back in time as the historical record allows (mid 1940s). Rates were calculated every 50 meters along both the open-ocean/barrier coast and the lagoon coast along the entire North Slope (Figure 2). Some of the highest erosion rates in the world were measured between Drew Point and Cape Halkett (~18 m/yr), although average shoreline change rates for the study area were considerably lower, averaging -1.7 m/yr and -0.3 m/yr along the Beaufort and Chukchi Sea coasts, respectively. Historical shoreline change studies provide useful information to identify vulnerable and critically retreating coastlines.



North Coast Alaska Shoreline Change Rates 1940s-2000s

III. Flooding Hazards and Coastal Processes

Measurements of water levels at the coast are needed to document storm surge levels and coastal inundation. Unfortunately there are very few actual measurements along Alaska's Arctic coast (only one continuously recording tide gauge is available at Prudhoe Bay since 1996 (NOAA). In lieu of measurements, and with the aim of estimating future storm surge levels in response to changing atmospheric conditions expected with climate change, we used a state-of-the-art numerical model (Deltares Delft3D) to simulate storms and responding water levels in response to passing storms. Wind and atmospheric pressure fields derived from re-analysis products and a suite of Global Climate Models (GCM) were used to hind-cast and prepare estimates of future storm surge levels in response to climate change. Model results suggest that storm surge levels will increase in the Arctic, and for the RCP 4.5 'stabilizing' scenario (see Figure 3). Peak surges are expected to occur sometime during the mid-part of the 21st century. For example, in northeast Alaska the 25-year and maximum events for the first half of the century are 1.70 m and 1.95 m above approximate mean sea level (aMSL), respectively. Because of the typical low relief landscape this translates to > 6 km^2 of flooded tundra, much of which consists of salt-intolerant vegetation.

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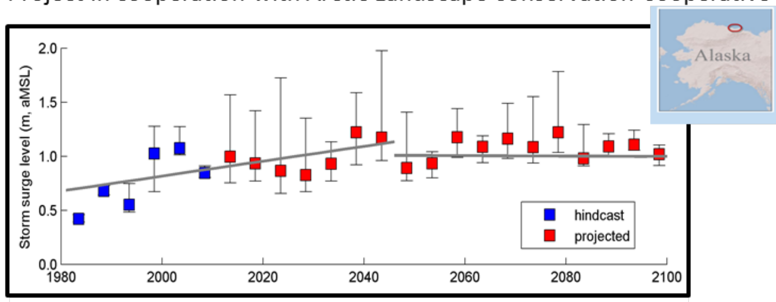
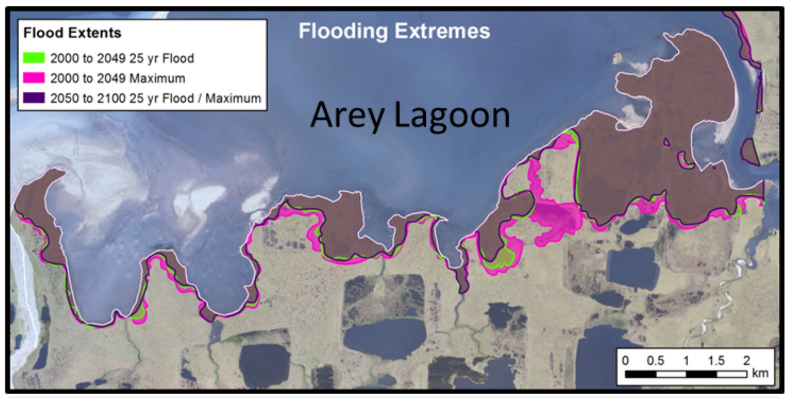
Project in cooperation with Arctic Landscape Conservation Cooperative



Time-series plot of the highest storm surge levels (including an assumed sea level rate of 3.5mm/yr) simulated with a numerical model for the years 1981 through 2100.

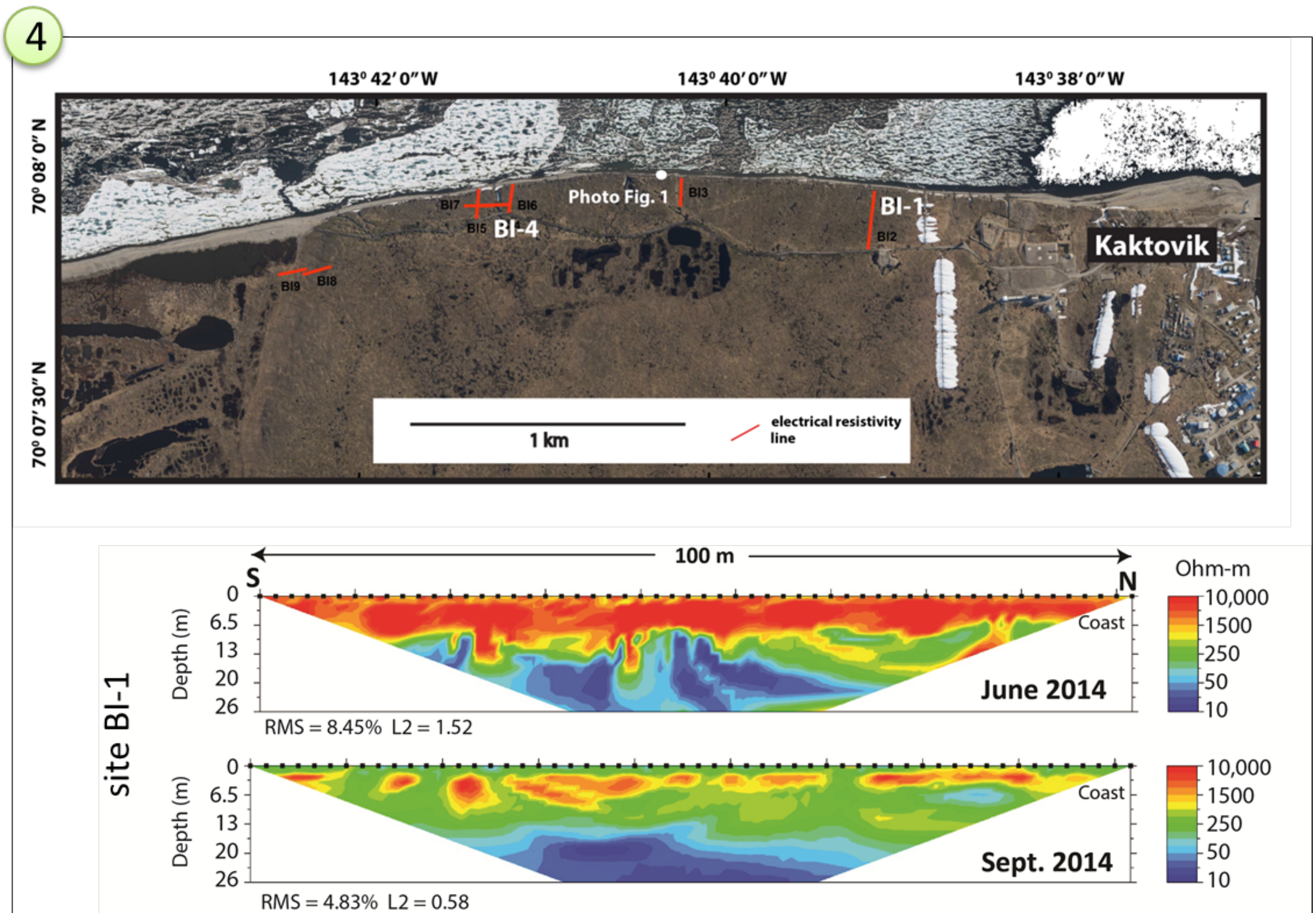


Extents of saltwater flooding as derived by allowing the maximum and 25-year return period storm surge levels to flood a high resolution digital elevation model.

Numerical modeling has been extended to the Bering Sea. In partnership with Alaska Division of Geological and Geophysical Surveys we have investigated the contribution of varying components to the overall water level that might occur during a storm at three specific sites. Specific locations dictate the relative contributions of astronomic tide, storm surge, and wave runup that might cause flooding. Return period curves, can be used to estimate the frequency and magnitude of extreme events that might cause saltwater flooding.

IV. Subsurface water flow

As part of a combined geochemical and geophysical reconnaissance, multichannel electrical resistivity tomography (ERT) was used to image shallow subsurface features such as permafrost, the active layer (zone of summer surface thawing), and a coastal bluff face on Barter Island, northeast Alaska. Processed ERT images show dramatic changes in the both shallow and deeper features from June to September, 2014. For example, a shore-perpendicular survey line conducted in September on top of the bluff reveals a thawed active layer that was still frozen in June (Figure 5). During June, when the upper active layer was still completely frozen, many ERT images show pronounced vertical features that are either subdued or not present at all during the September surveys. These features may represent ubiquitous ice-wedge polygon boundaries with unique freeze-thaw cycles. A June-September comparison of such a survey line suggests that ERT effectively captured how the bluff face and tundra sediment changed during one summer thaw cycle. These electrical geophysical methods provide new insights into how subsurface features can change over one summer, with obvious implications to coastal bluff stability and material efflux to the atmosphere and coastal ocean.



Upper figure shows electrical resistivity survey lines (red lines) collected along and parallel to the coastal bluffs west of Kaktovik, Alaska in June and September, 2014. Lower figure shows ERT measurements at the beginning and end of summer / early fall for transect BI-1.